Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 61 (2014) 542 – 546
Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Study on the Effect of the Nozzle Diameter and Swirl Ratio on the Combustion Process for an Opposed-piston Two-stroke Diesel Engine

Zhenyu Zhang, Changlu Zhao, Zhaoyi Xie,Fujun Zhang, Zhenfeng Zhao*

Beijing Institute of technology, 5 South Zhongguancun Street, Beijing 100081, China

Abstract

There are great differences between combustion in the opposed-piston two-stroke diesel engine and conventional diesel engine, because of the different injection position and the relative position between the spary and the in cylinder flow. In this paper, CFD models base on AVL-FIRE were established. Effects of the nozzle diameter and swirl ratio on the engine combustion were calculated and studied, and matching criteria of nozzle diameter and swirl ratio were summarized. The results show that,the smaller nozzle diameters means the smaller droplet diameters after collapse; Moreover, a proper swirl ratio can improve the mixing process, but if it is too large, droplets are likely to diverge and then accumulate in a restricted region, resulting in the form of rich mixture regions. The best nozzle diameter is 0.1mm while the best swirl ratio is 1.0.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: Opposed-piston two-stroke; diesel engine; nozzle diameter; swirl ratio

1. Introduction

The increasing focus on the fuel efficiency, power density and emission of vehicle engine requirements has led to increasing research efforts into innovative engine technology. For this reason, many researchers have done many optimized works on the conventional engines. However, plenty of new types of unconventional engines were also come into the picture [1-2]. Opposed-piston two-stroke folded-cranktrain diesel engine (OPFC) is one of them. In contrast with conventional engine, opposed-piston engine has many fundamental advantages. The opposed-piston structure, characterized by two pistons reciprocating opposite to each other in a common cylinder, piston portings were allowed by two moving

* Corresponding author.Zhenfeng Zhao: Tel.: +086-010-68912259; fax:+086-010-68912514.
E-mail address: zhzhf@bit.edu.cn.

Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.11.1166

pistons which cancelled the cylinder head and valve mechanism, which results in the lower heat transfer loss in the cylinder. The nearly symmetric movement of the opposed pistons lead to an excellent engine balance performance even for single-cylinder configurations. For the OP arrangement has no cylinder head, the fuel injector must be installed in the cylinder liner, the interaction between the fuel spray and the in-cylinder fresh-charge motion with traditionally high swirl resulted in combustion occurring near the combustion-chamber surfaces [3]. There are great differences between opposed-piston two-stroke diesel engine combustion and conventional diesel engine combustion.

Nomenclature

OP2S	opposed piston two-stroke engine
CI	compression ignition
TDC	top dead centre
ATDC	after top dead centre
BDC	bottom dead centre
ABDC	after bottom dead centre
IPC	Intake port closing time
EPO	Exhaust port opening time

2. CFD modelling and setting

Fig 1 shows the OPFC combustion chamber, two pistons placed in each cylinder liner, the combustion chamber was formed when the two pistons moved to the most closed position. CFD calculations of the combustion were conducted using AVL Fire 2010. Fire fame engine was used to generate the moving meshes; the mesh was refined near the TDC, in order to capture the great flow grads accurately. As is show in Fig 2, the Fire grid comprised of 96526 cells at scavenging process and 59218 cells at compression process after rezone. The initial conditions and piston motion were extracted from the one dimensional simulation model. The flow field was initialized by specifying the temperature, pressure and the turbulence intensity. While k-ζ-f mode was employed as turbulence mode; WAVE mode was employed as breakup model; Walljet mode was employed as wall interaction model; Dukowicz mode was employed as evaporation model; EBU mode was employed as combustion mode. The combustion process was from IPC to EPO [4]. The pressure-crank angle diagram form the simulation is presented in Fig 3, the test cylinder pressure is also presented in Fig 3 which is agreement with predicted values from the simulation.

Table 1. CFD model setting

Type	Value	Type	Value
Bore/mm	100	Compression ratio	16:1
Stroke/mm	110×2	Engine speed/($r\cdot min^{-1}$)	2500
IPC/BTDC	113°	EPO/ATDC	100°

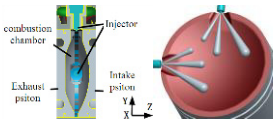


Fig 1. OP2S combustion chamber

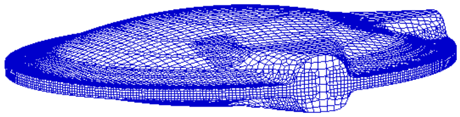


Fig 2. CFD meshes

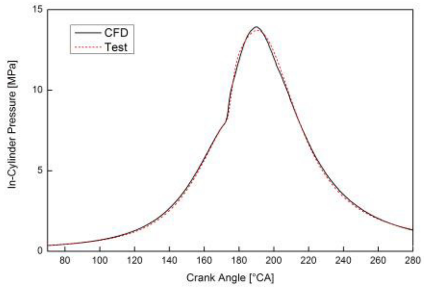


Fig 3. Comparison of measured and simulated in-cylinder pressure

3. Results and discussion

F/A equivalence ratio is abbreviation for the fuel-air equivalence ratio, which is defined as the ratio of the fuel-to-oxidizer ratio to the stoichiometric fuel-to-oxidizer ratio. Fig 4 shows the influences of swirl ratio and nozzle diameter on the in-cylinder fuel equivalent ratio distribution. For the nozzle diameter determine the fuel droplet diameters, the smaller nozzle diameter, and the more uniform in-cylinder fuel equivalence ratio distribution. Swirl ratio has a more complicated impact on the in-cylinder fuel equivalence ratio distribution because the in-cylinder center equivalence ratio decreases largely when the swirl ratio increases from 0 to 1.0. However, as the swirl ratio continues to increase, the in-cylinder center equivalence ratio increases due to the decreasing density.

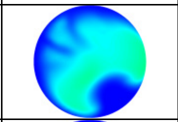
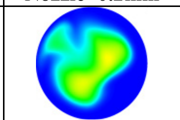
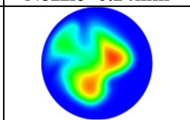
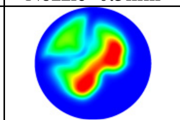
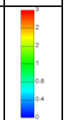
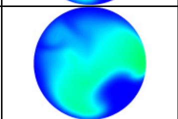
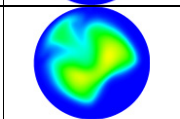
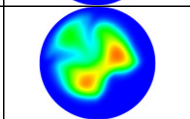
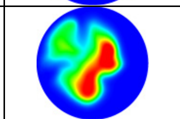
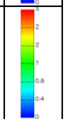
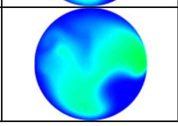
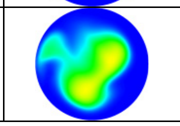
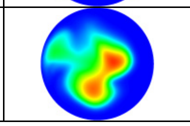
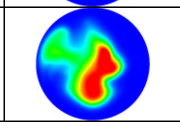
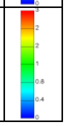
	Nozzle=0.1mm	**Nozzle=0.2mm**	**Nozzle=0.24mm**	**Nozzle=0.3mm**	
Swril ratio=0					
Swril ratio=1.0					
Swril ratio=2.0					

Fig 4. Fuel-to-air equivalence ratio under various nozzle diameters and swril ratio(15ATDC)

Fig 5 shows the in-cylinder pressure under various nozzle diameters and swril ratios, the maximum cylinder mean pressure reduces with the nozzle diameter increases. It also affect by swirl, when the swirl ratio is 1.0 engine get a good mean pressure result in a better combustion process as is shown in the Fig 6.

Fig 7 shows the effects of swirl ratios and nozzle diameters on the indicated mean effective pressure (IMEP). IMEP will be improved since the maximum pressure will be enlarged with a reducing nozzle diameter. In addition, IMEP is parabolic with the swirl ratio and a proper swirl ratio will promote the combustion process, so the maximum pressure will increase and IMEP will also increase. But IMEP will be reduced if the swirl ratio is too large. Fig 8 shows the matching criteria of nozzle diameters and swirl ratios for optimizing the IMEP. Smaller nozzle diameters and proper swirl ratios are the two matching criteria for the opposed-piston two-stroke diesel engines. When the swirl ratio is kept in the range of 0.8-1.4, engines can achieve an outperforming IMEP if the nozzle diameter is in the range of 0.1-0.18mm.

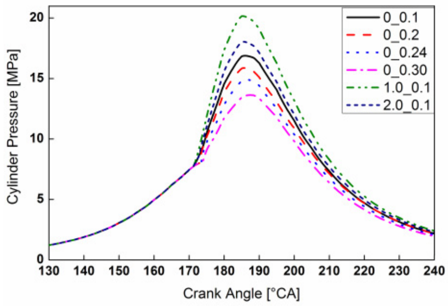


Fig 5. In-cylinder pressure under various nozzle diameter and swril ratio

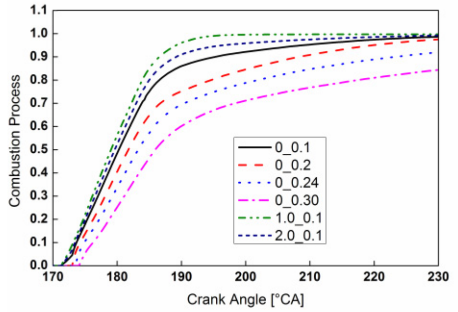


Fig 6. Combustion process under various nozzle diameter and swril ratio

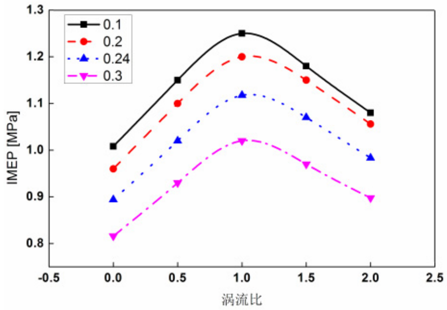


Fig 7. IMEP under various nozzle diameter and swril ratio

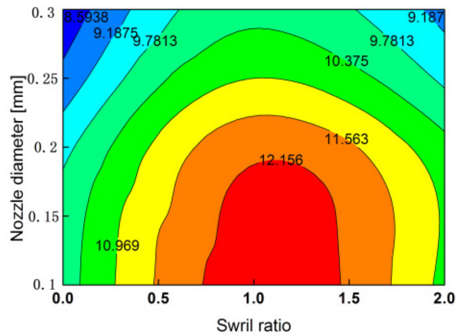


Fig 8. Matching criteria of nozzle diameter and swirl ratio for optimizing the IMEP

4. Conclusions

(1) The smaller nozzle diameters means the smaller droplet diameters after collapse; Moreover, a proper swirl ratio can improve the mixing process, but if it is too large, droplets are likely to diverge and then accumulate in a restricted region, resulting in the form of rich mixture regions.

(2) There is a strong interaction between nozzle diameters and swirl ratios so that a smaller nozzle diameter and appropriate swirl ratio are chosen for matching criteria. An optimum nozzle diameter should be confined in 0.1mm while swirl ratio in 1.0.

References

[1] Pirault, J.-P. and Flint, M. Opposed Piston Engines:Evolution, Use, and Future Applications. SAE International, Warrendale, PA, ISBN 978-0-7680-1800-4, 2009, doi:10.4271/R-378.

[2] Heywood JB. Internal combustion engines fundamentals. McGraw Hill International; 1988.

[3] Franke M, Huang H, Liu J P, et al. Opposed Piston Opposed Cylinder (opoc™) 450 hp Engine: Performance Development by CAE simulations and Testing [C]. SAE Paper 2006-01-0277, 2006.

[4] AVL Company. FIRE Version 8 Examples. 2003.

Biography

This is Zhang zhenyu, PHD candidate of school of mechanical engineering, Beijing institute of technology, majoring in Power Engineering and Engineering Thermophysics in School of Mechanical and Vehicle Engineering. His research is focus on diesel engine In-cylinder gas motion and combustion.